MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 3, 2021/2022

EEL2216 – CONTROL THEORY
(LE / EE / CE / NE / TE)

8 AUGUST 2022
9:00AM – 11:00AM
(2 hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of **FIVE** pages including cover page with **FOUR** questions only.

2. Answer **ALL** questions and print all your answers in the answer booklet provided.

3. All questions carry equal marks and the distribution of the marks for each question is given.

Question 1

(a) Briefly compare the advantage and disadvantage of a closed-loop control system with an open-loop control system. [4 marks]

(b) Given the following differential equation, solve for $y(t)$ under zero initial conditions using Laplace Transform. [8 marks]

$$\frac{d^2y(t)}{dt^2} + 8\frac{dy(t)}{dt} + 15y(t) = 15u(t)$$

(c) Using Mason's rule, find the transfer function, $\frac{C(s)}{R(s)}$ for the signal-flow graph shown in Figure Q1. [13 marks]

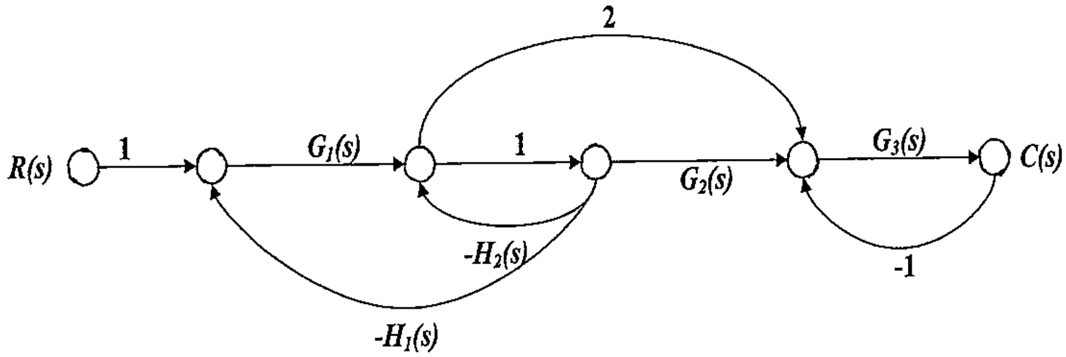

Figure Q1

Question 2

(a) It is given that a second order system has a damping ratio of 0.6 and a natural frequency of 10 rad/s.
(i) Find the characteristic equation of the system, $\Delta(s)$. [3 marks]
(ii) Hence, determine the settling time and percent maximum overshoot of the system given a step input. [3 marks]

(b) For a negative unity feedback system with open-loop transfer function as given below, determine the range of stability for K using the Routh-Hurwitz criterion. [6 marks]

$$G(s) = \frac{K(s+6)}{(s^2+s)(s+3)}$$

(c) For the following loop transfer function, sketch the root locus, showing all the steps clearly. Hence, determine the range of K for stability. [13 marks]

$$KG(s)H(s) = \frac{K}{(s+3)(s+5)}$$

Continued...

Question 3

The forward path transfer function of a negative unity feedback system is given by

$$G(s) = \frac{1}{s(s+2)(s+4)}.$$

(i) Determine the magnitude and phase of $G(j\omega)$ at $\omega = 0$ and $\omega = \infty$. Using these information, sketch the Nyquist plot. [13 marks]

(ii) Calculate the intersection point of the Nyquist plot with the negative real axis. [8 marks]

(iii) Based on your answers in parts (i) and (ii), evaluate whether a negative unity feedback system with forward path transfer function $G_{new}(s) = \dfrac{50}{s(s+2)(s+4)}$ is stable. Justify your answer. [4 marks]

Question 4

(a) Figure Q4 shows an implementation of a proportional-integral (PI) controller.

(i) Derive the transfer function, $E_o(s)/E_{in}(s)$, showing clearly the gains of both stages of the circuit. Obtain the proportional constant, K_P and integral constant, K_I in terms of the circuit components. [7 marks]

(ii) State the main function of a PI controller and briefly explain how this is achieved in terms of the characteristics of the controller transfer function. [3 marks]

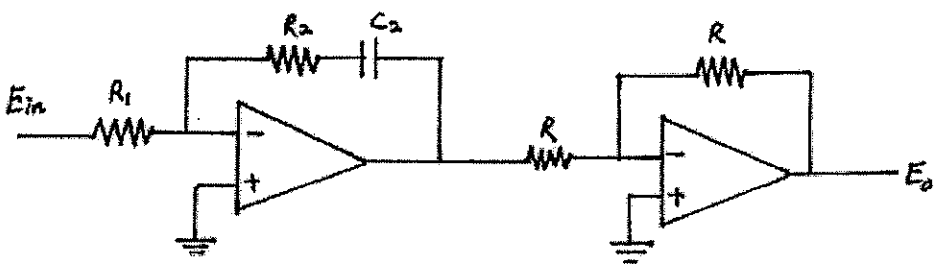

Figure Q4

(b) A unity feedback control system has a forward path transfer function, $G(s) = \dfrac{K}{s(s+6)}$. A controller is to be designed such that the ramp error constant is 10 and the damping ratio is 0.8 for the closed-loop system. Design a phase-lag controller to meet the requirements. [15 marks]

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Appendix - Laplace Transform Pairs

$f(t)$	$F(s)$
Unit impulse $\delta(t)$	1
Unit step $1(t)$	$\frac{1}{s}$
t	$\frac{1}{s^2}$
$\frac{t^{n-1}}{(n-1)!} \quad (n = 1, 2, 3, \ldots)$	$\frac{1}{s^n}$
$t^n \; (n = 1, 2, 3, \ldots)$	$\frac{n!}{s^{n+1}}$
e^{-at}	$\frac{1}{s+a}$
te^{-at}	$\frac{1}{(s+a)^2}$
$\frac{t^{n-1}}{(n-1)!}e^{-at} \quad (n = 1, 2, 3, \ldots)$	$\frac{1}{(s+a)^n}$
$t^n e^{-at} \; (n = 1, 2, 3, \ldots)$	$\frac{n!}{(s+a)^{n+1}}$
$\sin \omega t$	$\frac{\omega}{s^2+\omega^2}$
$\cos \omega t$	$\frac{s}{s^2+\omega^2}$
$\sinh \omega t$	$\frac{\omega}{s^2-\omega^2}$
$\cosh \omega t$	$\frac{s}{s^2-\omega^2}$
$\frac{1}{a}(1-e^{-at})$	$\frac{1}{s(s+a)}$
$\frac{1}{b-a}(e^{-at}-e^{-bt})$	$\frac{1}{(s+a)(s+b)}$
$\frac{1}{b-a}(be^{-bt}-ae^{-at})$	$\frac{s}{(s+a)(s+b)}$
$\frac{1}{ab}\left[1+\frac{1}{a-b}(be^{-at}-ae^{-bt})\right]$	$\frac{1}{s(s+a)(s+b)}$

Continued...

Appendix - Laplace Transform Pairs (continued)

$\frac{1}{a^2}(1-e^{-at}-ate^{-at})$	$\frac{1}{s(s+a)^2}$
$\frac{1}{a^2}(at-1+e^{-at})$	$\frac{1}{s^2(s+a)}$
$e^{-at}\sin\omega t$	$\frac{\omega}{(s+a)^2+\omega^2}$
$e^{-at}\cos\omega t$	$\frac{s+a}{(s+a)^2+\omega^2}$
$\frac{\omega_n}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin\omega_n\sqrt{1-\zeta^2}t$	$\frac{\omega_n^2}{s^2+2\zeta\omega_n s+\omega_n^2}$
$-\frac{1}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin(\omega_n\sqrt{1-\zeta^2}t-\phi)$ $\phi=\tan^{-1}\frac{\sqrt{1-\zeta^2}}{\zeta}$	$\frac{s}{s^2+2\zeta\omega_n s+\omega_n^2}$
$1-\frac{1}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin(\omega_n\sqrt{1-\zeta^2}t+\phi)$ $\phi=\tan^{-1}\frac{\sqrt{1-\zeta^2}}{\zeta}$	$\frac{\omega_n^2}{s(s^2+2\zeta\omega_n s+\omega_n^2)}$
$1-\cos\omega t$	$\frac{\omega^2}{s(s^2+\omega^2)}$
$\omega t-\sin\omega t$	$\frac{\omega^3}{s^2(s^2+\omega^2)}$
$\sin\omega t-\omega t\cos\omega t$	$\frac{2\omega^3}{(s^2+\omega^2)^2}$
$\frac{1}{2\omega}t\sin\omega t$	$\frac{s}{(s^2+\omega^2)^2}$
$t\cos\omega t$	$\frac{s^2-\omega^2}{(s^2+\omega^2)^2}$
$\frac{1}{\omega_2^2-\omega_1^2}(\cos\omega_1 t-\cos\omega_2 t)\quad(\omega_1^2\neq\omega_2^2)$	$\frac{s}{(s^2+\omega_1^2)(s^2+\omega_2^2)}$
$\frac{1}{2\omega}(\sin\omega t+\omega t\cos\omega t)$	$\frac{s^2}{(s^2+\omega^2)^2}$

End of Paper